EXCITATION PROCESSES IN THE NIGHT SKY
AND THE AURORA

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Received July 2, 1943
(Communicated by Sir C. V. Raman, Kt., F.R.S., N.L.)

Introduction

Our knowledge concerning the conditions prevailing in the upper atmosphere
of the earth comes mainly from the following two sources: (1) From the
behaviour of the ionized layers towards radio waves and the magnetic
variations, it is possible to make certain estimates of the concentrations of
electrons, heavy ions and neutral particles in the different layers. In the
present work, we shall not be concerned with the various aspects of these
problems. Suffice it to summarize the main results as follows:

<table>
<thead>
<tr>
<th>Electron density</th>
<th>Heavy ion density</th>
<th>Collision freq. of electron</th>
<th>Concentration of neutral particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>Night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F layer 200–300 km</td>
<td>$3 \times 10^5$/c.c.</td>
<td>$2 \times 10^5$/c.c.</td>
<td>$10^5$–$10^6$/c.c.</td>
</tr>
<tr>
<td>E layer 100 km.</td>
<td>$1.5 \times 10^5$/c.c.</td>
<td>$8 \times 10^3$/c.c.</td>
<td>$10^6$/c.c.</td>
</tr>
</tbody>
</table>

The ionization and the dissociation of the atoms and molecules are due to
the ultraviolet radiations from the sun. The rather slow falling off of the
electron density after sunset and the much higher concentration of heavy
ions than that of electrons, are due to the small probability of recombination
between electrons and positive ions and the much more frequent occurrence
of attachment process of electrons to neutral atoms and molecules, the former
process taking place at the rate of about $10^{-5}$ per second and the latter about
1 per second at the pressure of the E layer.

(2) From the analysis of the spectra of the night sky and the aurora,
it is found that in both cases the radiations consist of the forbidden lines of

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1 Cf. H. S. W. Massey, *Negative Ions*, 1938, Cambridge Univ. Press (1938), pp. 89-100. Later results are unfortunately not available to the writer, but they would not affect the discussions in the following.

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[OI], the various band systems of N\(_2\) and N\(_2^+\), some weak bands of O\(_2\) and H\(_2\)O and some lines or bands of uncertain origin. There is a great difference, however, between the spectrum of the night sky and that of the aurora borealis, namely, the negative bands of N\(_2^+\) are very strong in the latter but very weak in the former, while the Vegard-Kaplan bands of N\(_2\) are very strong in the former but rather weak in the latter. In each individual band system, certain bands in certain sequences are particularly enhanced. Evidently a clear understanding of the excitation mechanisms of these radiations will contribute greatly to our knowledge of the conditions in the upper atmosphere of the earth. For convenience of the discussion, we shall summarize the main features of the spectra of the night sky and the aurora as follows:

(a) The forbidden lines of [OI].—The green line at 5577 Å is by far the most intense line in the spectrum of the night sky and is also very intense in the aurora. The red lines at 6300 and 6364 Å are inferior in intensity in both cases, but are still fairly strong compared with the other bands in each spectrum. In the night sky, the green line increases very slowly in intensity and reaches a maximum towards midnight after which it decreases slowly again. The red lines on the other hand have the greatest intensity immediately after sunset and fall off gradually in the night. In the sunlit aurora, the red lines are found to be greatly enhanced relative to the green one.

(b) First negative bands of N\(_2^+\).—In the aurora spectrum, the following negative bands of N\(_2^+\) are very intense:

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\begin{align*}
4708 \text{ Å } (v' = 0 \rightarrow v'' = 2), & \quad 4278 \text{ Å } (v' = 0 \rightarrow v'' = 1), & \quad 3914 \text{ Å } (v' = 0 \rightarrow v'' = 0), \\
4648 \text{ Å } (1 \rightarrow 3), & \quad 4236 \text{ Å } (1 \rightarrow 2), & \quad 4199 \text{ Å } (2 \rightarrow 3),
\end{align*}
\]

The 4708, 4278 and 3914 bands have comparable or even greater intensities than the green 5577 line in the ordinary aurora, and become very much more intense than the latter in sunlit aurora. In the night sky, perhaps only the 3914 band can be identified with certainty.

(c) Vegard-Kaplan bands of N\(_2\).—In the night sky spectrum, the radiations next in intensity to the forbidden lines of [OI] are the Vegard-Kaplan

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\(^2\) For a summary of the facts concerning the spectra of the aurora and the night sky, see, respectively, E. W. Hewson, *Rev. Modern Physics*, 1937, 9, 403; and G. Dejardin, *ibid.*, 1936, 8, 1, and references given there.

\(^3\) Cf. G. Dejardin, *loc. cit.*
